Converging in a Virtual World: The Complex Object.

by

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There are many things that can and should keep digitally-inclined scholars awake at night: things that promise opportunity and intellectual discovery; and other things that promise botheration and a mad scramble to keep up. In our work we have been preoccupied with two "C" words that have presented both botheration and opportunity: computation and convergence. With respect to the first, scholars in the past decade have witnessed the shift of computing to what Ray Kurzweil has referred to as "the second half of the chessboard" (Kurzweil, 1999: 37). Computers such as IBM's Watson, through a combination of brute computational power and A.I., now have the capacity to perform heretofore impossible tasks such as driving cars, making medical diagnoses and engaging in legal reasoning (Brynjolfsson and McAfee, 2014). Historians in the next couple of decades likely will find themselves using similar devices to locate relevant data on-line. With respect to convergence, we refer to a trend with which most of you are familiar: the aggregation of multiple tools into a single device in order to enhance the capabilities of users (Peddie, 2001). A smart phone is a well-known example of what we mean here. It integrates applications and devices such as the computer monitor, QWERTY keyboard, camera and phone into a single construct.

In this paper, our purpose is to argue that convergence is a process that will impinge on the future of historical GIS. Indeed, the process has already begun. One outcome of GIS' integration into a new software/hardware construct is that it will invite innovation: new formalisms and practices will be devised that will complement or replace existing ones found in GIS. In this contribution, we present one innovation for potential inclusion into this mix, the Complex Object, which we believe will emerge as a functional equivalent to the polygon in today's GIS. Our purpose here is to present the concept of the Complex Object, and to display an alpha version of the software we are developing to construct it.

Our rationale for this project stemmed from observation of two significant trends that emerged in the noughts of this century. The first trend was researcher adaptation to the opportunities and costs associated with the emergence of Big Data and High Performance Computing. Scholars in disciplines ranging from Physics to English Literature began to recognize, sometimes slowly, sometimes quickly, that the Internet, Moore's Law, and novel, distributed forms of HPC had endowed them with more data, and more ways to treat it, than any enjoyed by previous cohorts of scholars (Bonnett, 2009) (Manning, 2013) (Guldi and Armitage, 2014) (Jockers, 2013). The outcome of that realization was the articulation in fora such as the

National Centre or Supercomputing Applications (NCSA) and *Compute Canada* of user requirements for platforms capable of visualizing space at any scale and resolution, and time at any duration and increment. Researchers want tools that enable them to represent space in any mode they please, be it cartographic, photo-realistic, or both. They further want tools that will enable them to simulate the behaviour of physical, geological, biological, and historical systems at temporal scales ranging from the nanosecond to the millennium and beyond.[1]

The second driver of our project is the growing recognition in both business and the academy that extant applications such as GIS impose limitations on research, expression and analysis that need to be transcended. For this reason, one can identify calls in multiple literatures, ranging from GIScience and historical GIS to the digital humanities and history, for the integration of GIS with game engines and, more broadly virtual worlds (Bodenhamer, 2010: 26-28) (Lock, 2010: 97-101) (Harris, Corrigan and Bodenhamer, 2010: 171); Google Earth or an open source variant (Yuan, 2010: 116-117) (Harris, Rouse and Bergeron, 2010: 124-142); agent-based modeling software (Yuan and Hornsby, 2008: 10) (Bennett and Tang, 2008) (Lock, 2010: 97) and even high performance computing (Armstrong, 1995) (Stojanovic and Stojanovic, 2013) (Bonnett, 2015). One can also detect moves by vendors such as ESRI to address these limitations. In recent versions of ArcGIS, for example, the company has incorporated a digital globe akin to Google Earth. It has also, via its *CityEngine* plug-in, provided users with the capacity to rapidly generate photo-realistic 3D models using procedural modeling techniques. Finally, one can identify current research initiatives in archaeology such as the CRANE Project (Computational Research in the Ancient Near East) where scholars are moving now to integrate most of the above applications to support the integration, visualization and analysis of the social, economic and environmental data obtained from the Orontes Watershed of southeast Turkey.[2]

We suggest that these two trends will present an important consequent for researchers. To leverage the potential of their convergent applications, scholars will need to modify their tools, and design novel formalisms and workflows. Scholars will need to consider questions such as how a narrative or analysis will be expressed in a multi-modal environment. They will further needs to consider how the functionalities of one application – such as GIS – might be appropriated in the context of another, such as the Unity Game Engine. These realizations emerged as a result of John Bonnett's participation in an August 2009 *Institute for Advanced Topics in the Digital Humanities* workshop hosted by the NCSA, his participation in an interdisciplinary workshop hosted by *Compute* Canada, and the authors' participation in a SSHRC (Social Science and Humanities Research Council of Canada) Partnership Grant exploring Montreal's historic role as a hub for the circulation of people, goods and knowledge. The outcome of both initiatives was a thought experiment that explored historians' requirements for an HPC-supported virtual world, and the establishment of the *StructureMorph* project.

To gain purchase in our thought experiment, we recognized that we would need to narrow its terms considerably to proceed. We could not hope, for example, to specify user requirements for the discipline as a whole, nor could we hope to explore the implications that

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[1] These requirements were articulated by John Bonnett and explored by workshop participants at a National Endowment for the Humanities *Institute Advanced Humanities* workshop held at NCSA in 2009. Participants included Pat Dunae, University of Victoria, Richard Beacham and Drew Baker, King's College London, Alan Craig, Robert McGrath and Guy Garnett (NCSA), and William Thomas (University of Nebraska). They were articulated by John Bonnett and other participants at a 2012 *Compute Canada* meeting attended by researchers representing the sciences, social sciences and humanities. *Compute Canada* administers and coordinates Canada's HPC research clusters.

[2] See https://www.crane.utoronto.ca/

would result from integrating GIS with all the applications specified above. For that reason, we narrowed our focus to the user requirements of two domains: social history and architectural history. Such a focus was warranted, we believed, because within history both fields have been among the most active in appropriating computing, and specifying their requirements for the same. We further narrowed our focus by focusing on one scale of space: the urban level of spatial organization. And we finally narrowed the scope of our scenario by exploring the implications of converging just two applications: the game engine and GIS.

With these terms settled, we soon realized as we proceeded with our thought experiment that social and architectural historians would be asking a great deal from buildings as expressive objects in the HPC-platform we conceived. More specifically, we would be asking a given model to express two fundamental relationships: the relationship between the building and social data associated with it; and the relationship between the model and the primary source data that gave rise to it. With respect to the first requirement, we foresaw that the building would perform similar functions to those performed in GIS today. It would, for example, be tied to a social ontology, such as those expressed in census data, and a color ramp that would distinguish each category within a given ontology with a color. Therefore, we required models with the capacity to change their surface appearance from photo-realistic to symbolic modes in response to search queries from users. If a given address was lived in or operated by someone who was English, for example, we needed its affiliated model to turn red.

With respect to the second requirement, we believe, based on requirements emerging from the architectural history, theater history, digital archaeology and virtual heritage literatures, that scholars will require building models that reveal themselves to be mediated, temporal objects. They will need to show that the given 3D model is an imperfect construct, a construct that differentiates, again via color ramp, building constituents that are based on data, and building sections that are hypotheses, derived from the scholar's knowledge of architectural and building practices from the time. The structure will also need to possess expressive modes that support proper documentation. Here we are referring not only to the historian's long standing practice of documenting according to provenance. We are also referring to the emerging requirement in the literatures above that scholars should document workflow. Here, the imperative will be to show the thinking and decision-making that gave rise to the model in its final form. One important constituent of that accounting will be to create models with the capacity to display prior and competing versions of the given model, based on user prompting. The structure will finally require the capacity to show changes in its morphology and surface appearance that transpired over the course of the building's life cycle, based on user prompting, or changes in virtual world time.

To meet these requirements, the *StructureMorph Project* is contributing to the development of an expressive object that is gaining greater currency in the digital humanities: the Complex Object. There is no fixed definition of the qualities associated with the Complex Object, but among other things it is conceived as a hierarchical construct of many parts, one well suited to represent the multi-constituent object known as the building. It is also a heterogeneous object. It is not based on one mode of representation such as text. It is rather an amalgam of different expressive forms ranging from text to audio, 2D animations and 3D objects (Delve et al, 2012). We are contributing to this literature by suggesting that the Complex Object should not only be heterogeneous and hierarchical. It should also have the capacity to display more than one version of itself, and for this reason we are proposing an additional descriptor for the Complex Object: 3D Matrix (Bonnett, 2015).

So constituted, the Complex Object will be able to meet the expressive requirements we have set for it. It will be constituted of multiple three dimensional increments, or cells, and each cell will contain one of the potential versions of the model (See Figure One). The characteristics of a given iteration of the model will be determined by the location – the address – of the cell in which it finds itself. That address will be specified by its position relative to the three axes in the matrix. Each axis in the matrix will specify one of three things about the model:

- **Its temporal state** – Each increment along this axis will indicate a change in a structure's shape or surface appearance over the course of its life cycle. Each increment will be marked by the date in which the transformation took place (See Figure Two).
- **Its interpretive state** – Increments along this axis will refer to either the final version of the model, or prior versions of the model produced the model contributors (such as the penultimate and first versions), or by other scholars elsewhere (See Figure Three).
- **Its expressive state** – Each increment here will be automatically generated from the structures deposited along the temporal and interpretive axes. Our software will also tie each cell along this axis to a specific field in a database, a specific ontology and a color scheme aligning specific colors with categories in the ontology. Ontologies represented here will encompass everything from degrees of modeler confidence in building constituents to demographic categories (class, ethnicity) to economic sectors (See Figure Four).

Model expression will be determined by changes in virtual world-time or user interaction, promptings which will lead to the expression of one of the potential versions available within the matrix. The cell or increment that is activated will depend on the characteristics – the parameters – that are specified. The viewer or chronometer in the virtual world will tell the matrix what he/she/it wants to see. The Complex Object will reply by activating the cell and model version with the "address" that matches the combination of parameters specified by the viewer or virtual world (See Figure Five).

Currently, we are developing an alpha version of the software that will be dedicated to supporting the construction of Complex Objects, a plug-in that will operate in conjunction with the Unity 3D game engine. It will support the construction of the matrix – enabling users to define the number of increments along each axis, and to designate them. It will also allow users to perform a workflow where they upload their models to their designated matrices. This process will start with the user uploading a given model to a targeted virtual world (as shown in the mockup shown in Figure Six). The software will also permit modelers to structure their 3D model, to permit user filtration of model constituents. The process of filtration will enable a user, for example, to remove all constituents of a building save for one, such as building pilasters. (See the process of model structuring and model filtration shown in the mockup in Figure Seven). The next step in the workflow will center on tagging model constituents, designating which parts are based on data and which are based on modeler inference (See the mockup in Figure Eight). Users will then scale and position their models in the virtual world (Figure Nine), before annotating their model with multi-media narratives and documentation providing publication, bibliographic and paradata (data describing the workflow used to generate the structure) (Figure Ten). At this juncture, I will turn you over to my colleague Mark Anderson, who will display the functionalities we've been able to incorporate into *StructureMorph* software thusfar.

Figure One:

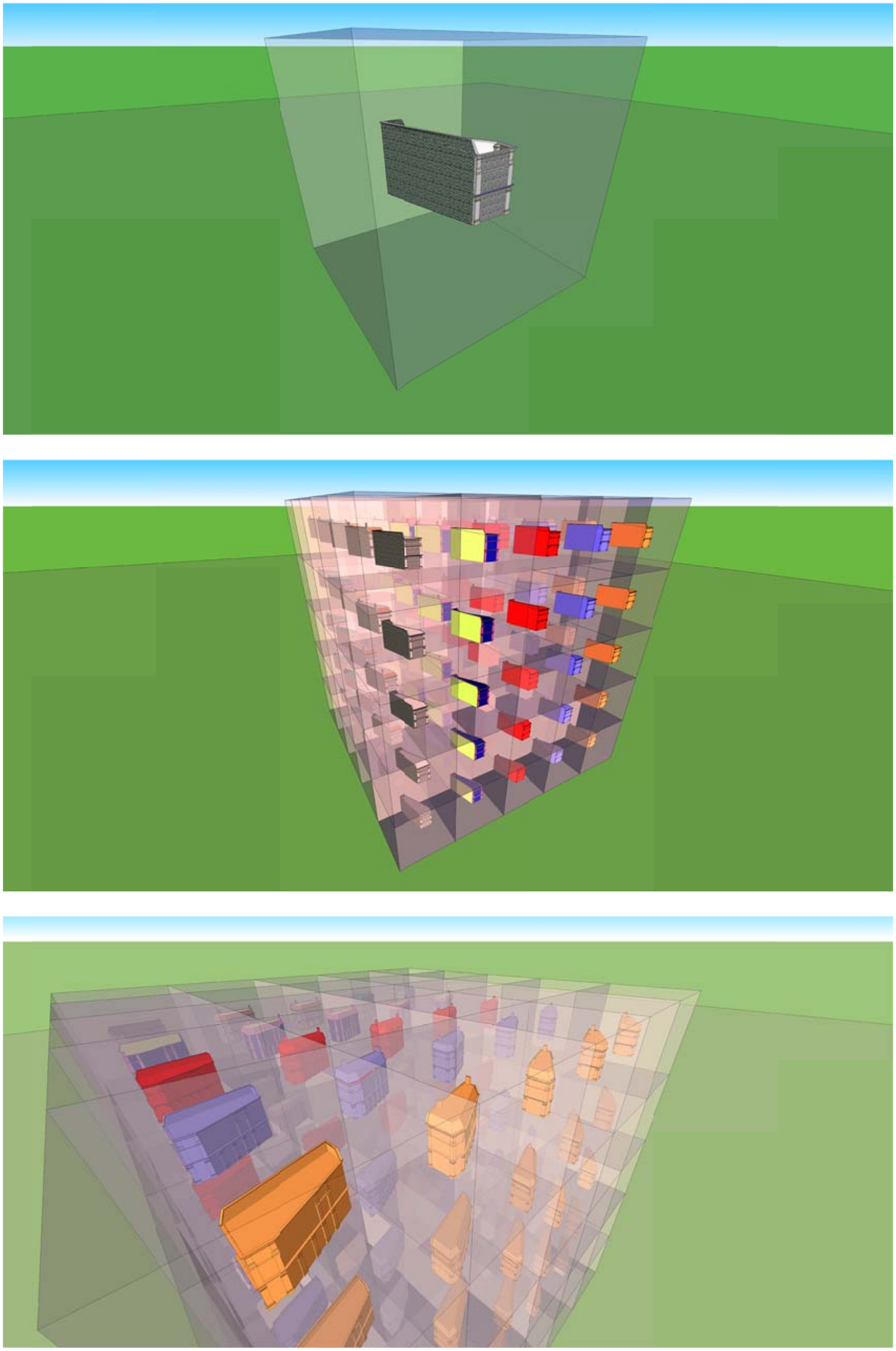


Figure Two:

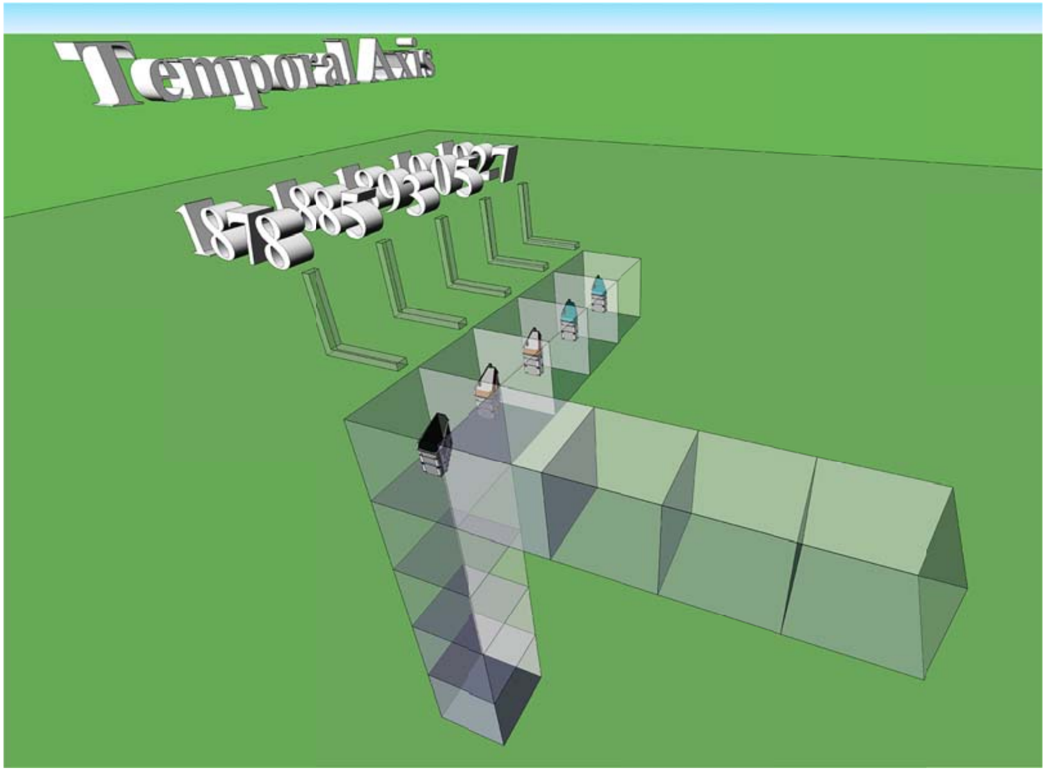


Figure Three:

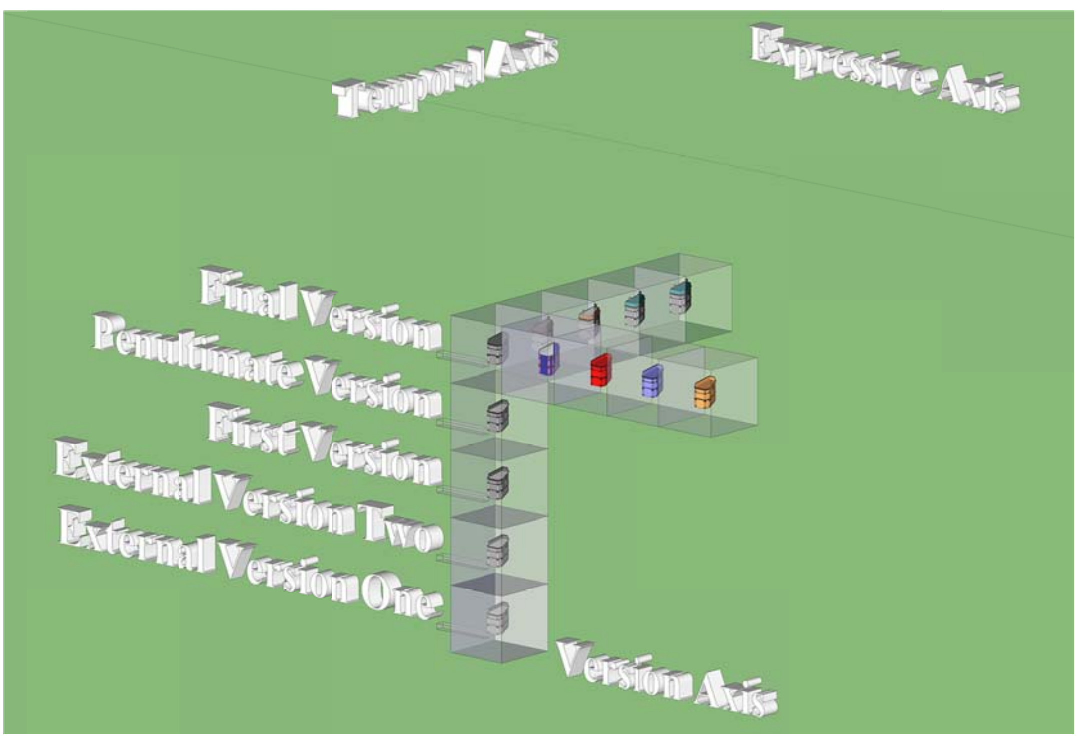
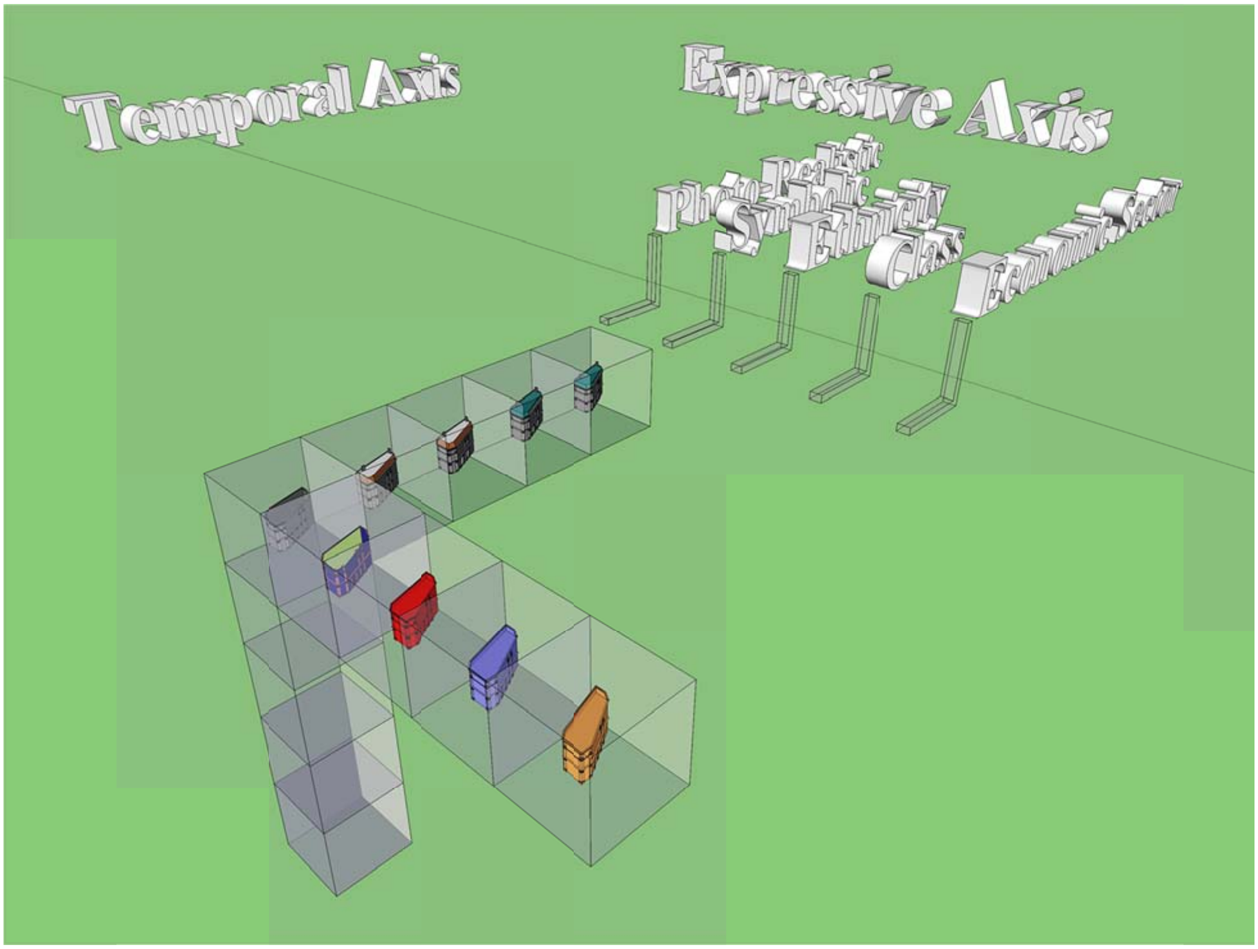


Figure Four:



Temporal Axis
Expressive Axis
Photo-Realistic
Symbolic
Ethnicity
Class
Economic Sector

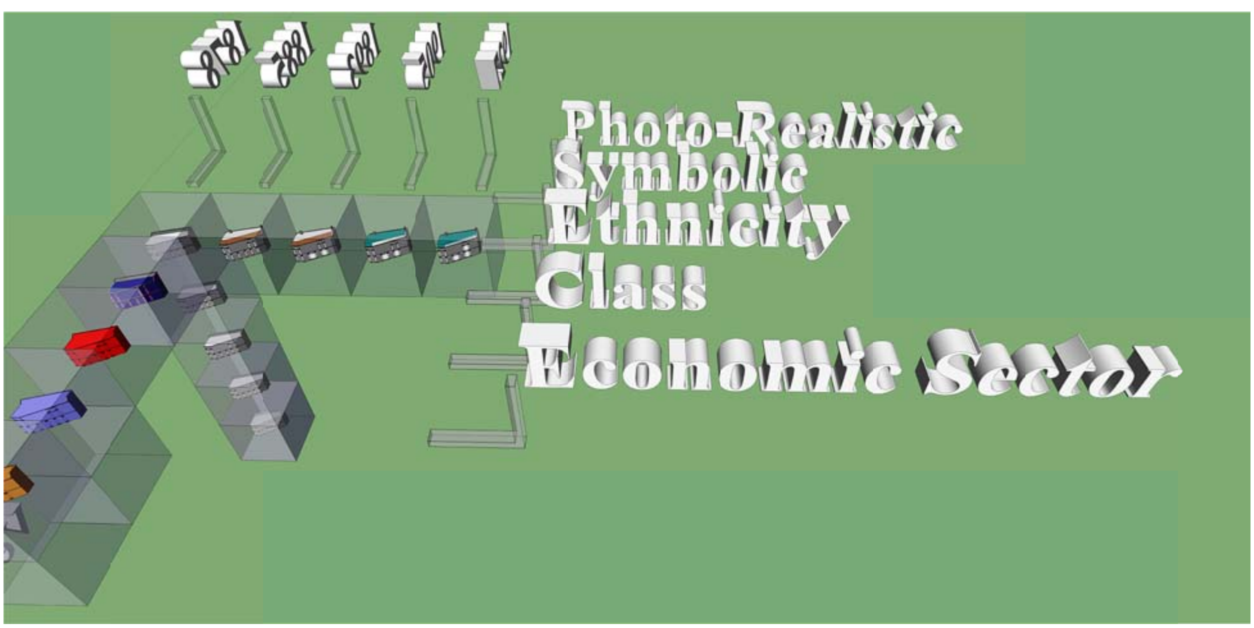


Photo-Realistic
Symbolic
Ethnicity
Class
Economic Sector

Figure Four Continued:

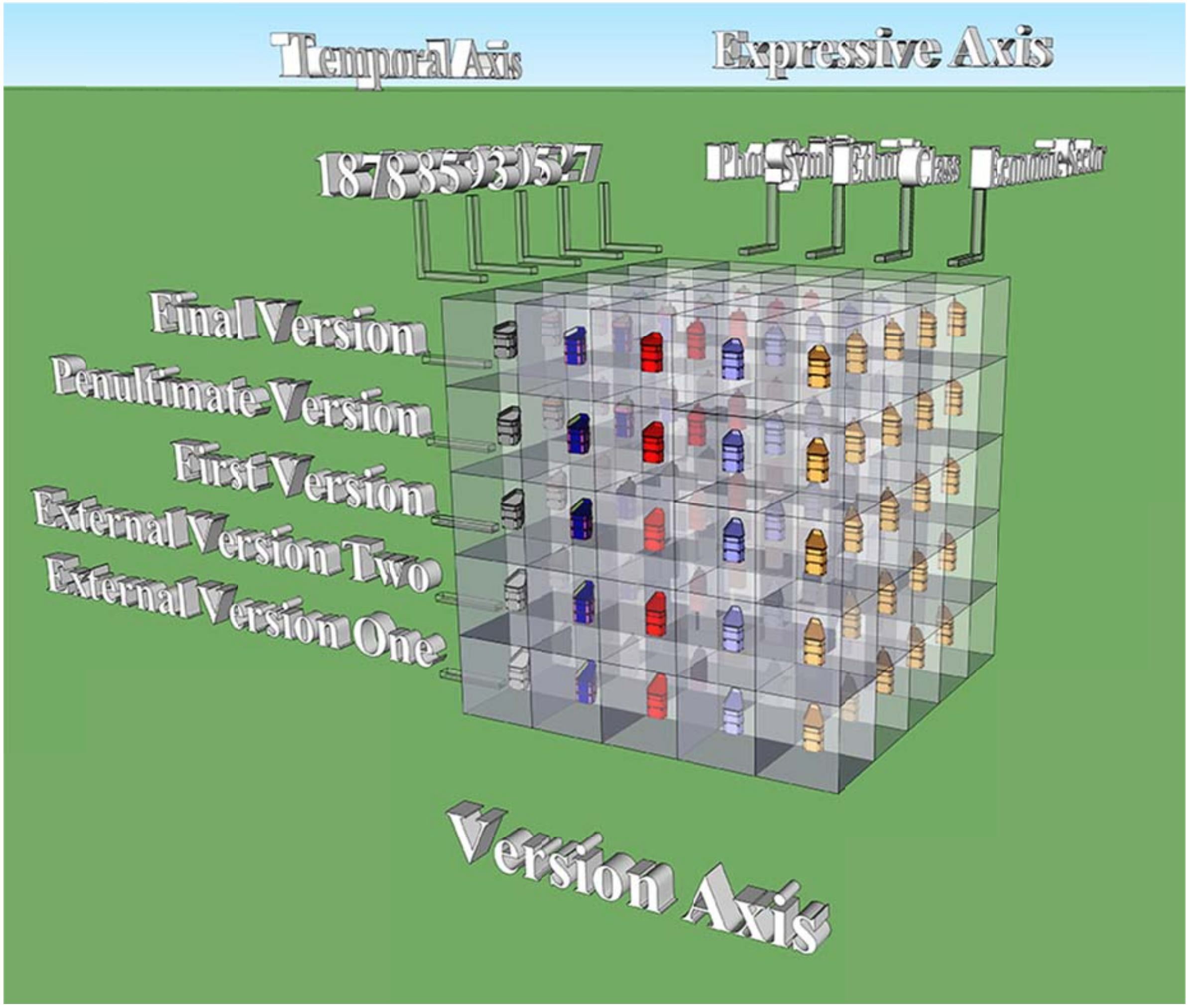


Figure Five:

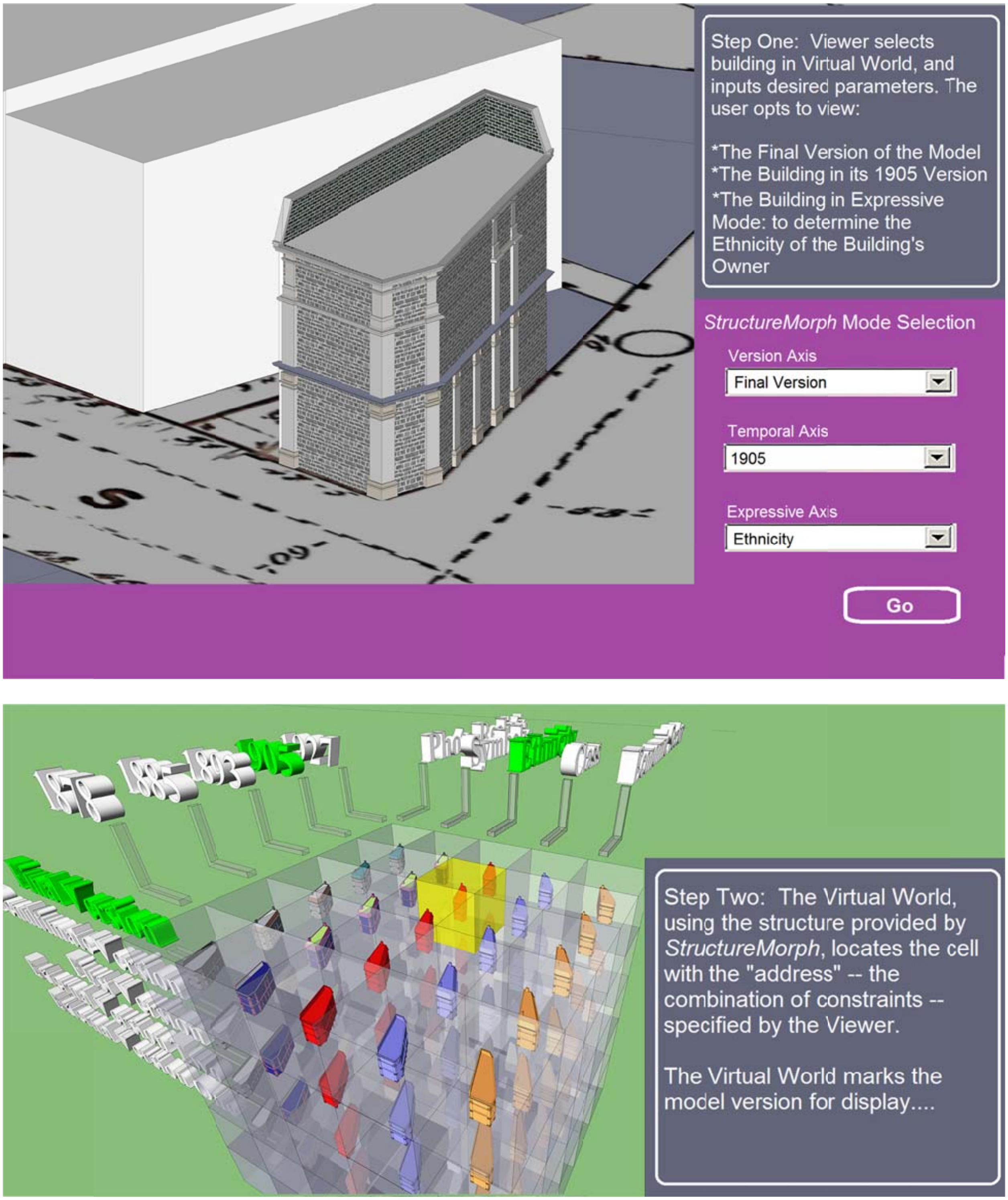

Step One: Viewer selects building in Virtual World, and inputs desired parameters. The user opts to view:
*The Final Version of the Model
*The Building in its 1905 Version
*The Building in Expressive Mode: to determine the Ethnicity of the Building's Owner
StructureMorph Mode Selection
Version Axis
Final Version
Temporal Axis
1905
Expressive Axis
Ethnicity
Go
Step Two: The Virtual World, using the structure provided by StructureMorph, locates the cell with the "address" -- the combination of constraints -- specified by the Viewer.
The Virtual World marks the model version for display....

Figure Five Continued:

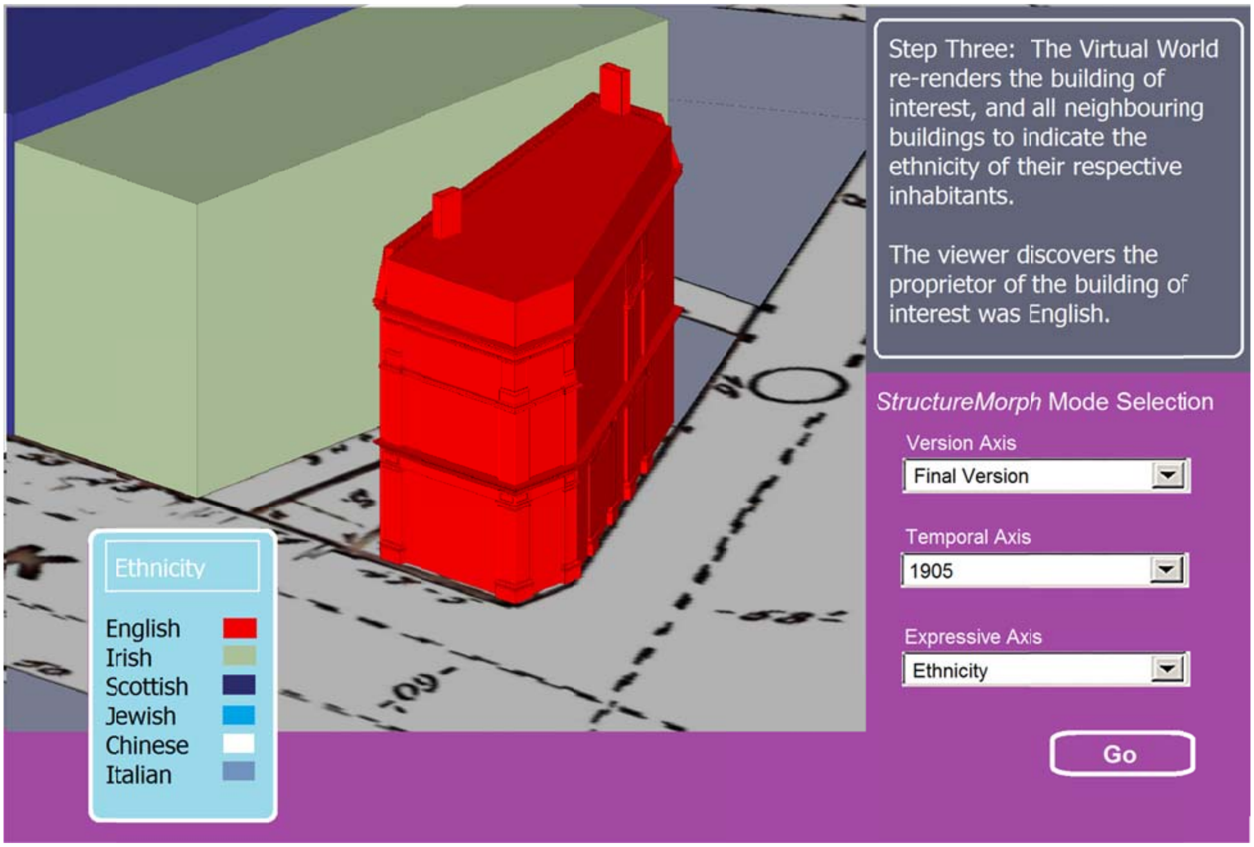
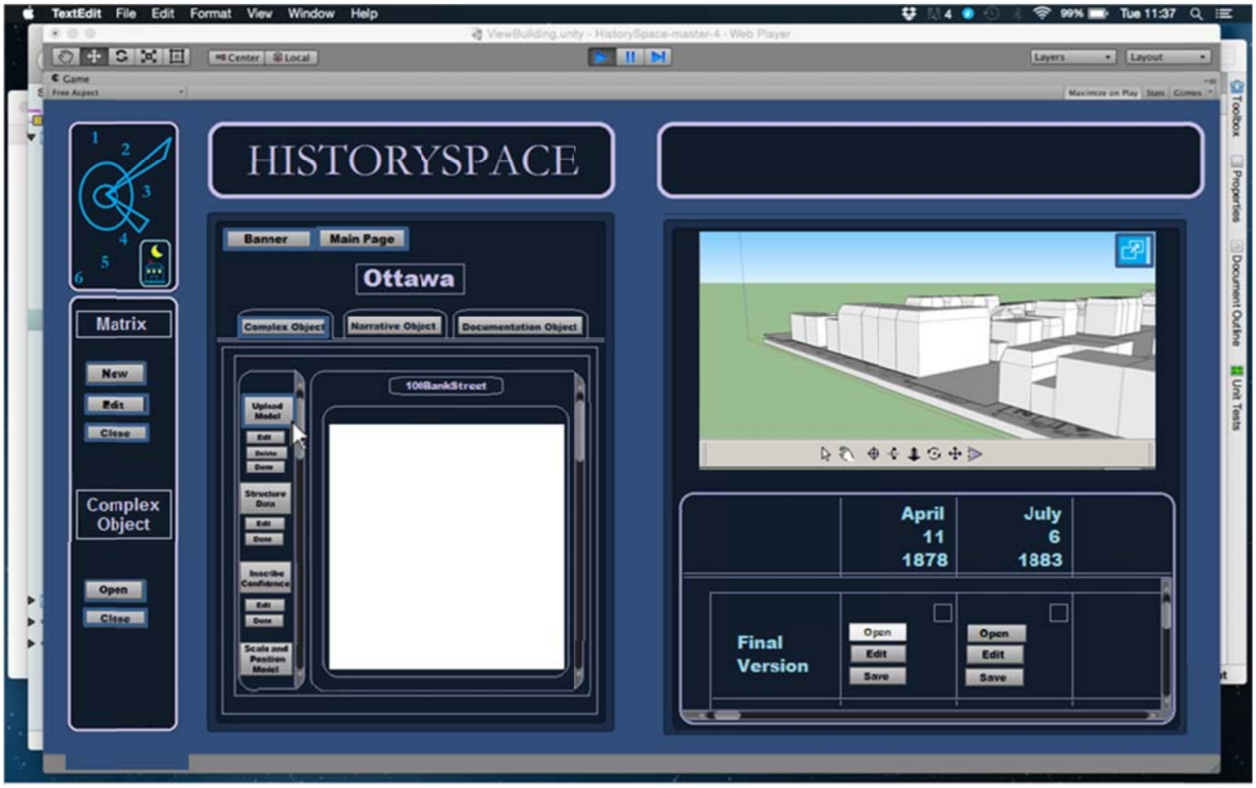


Figure Six: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July 6 1883
Final Version
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HISTORYSPACE
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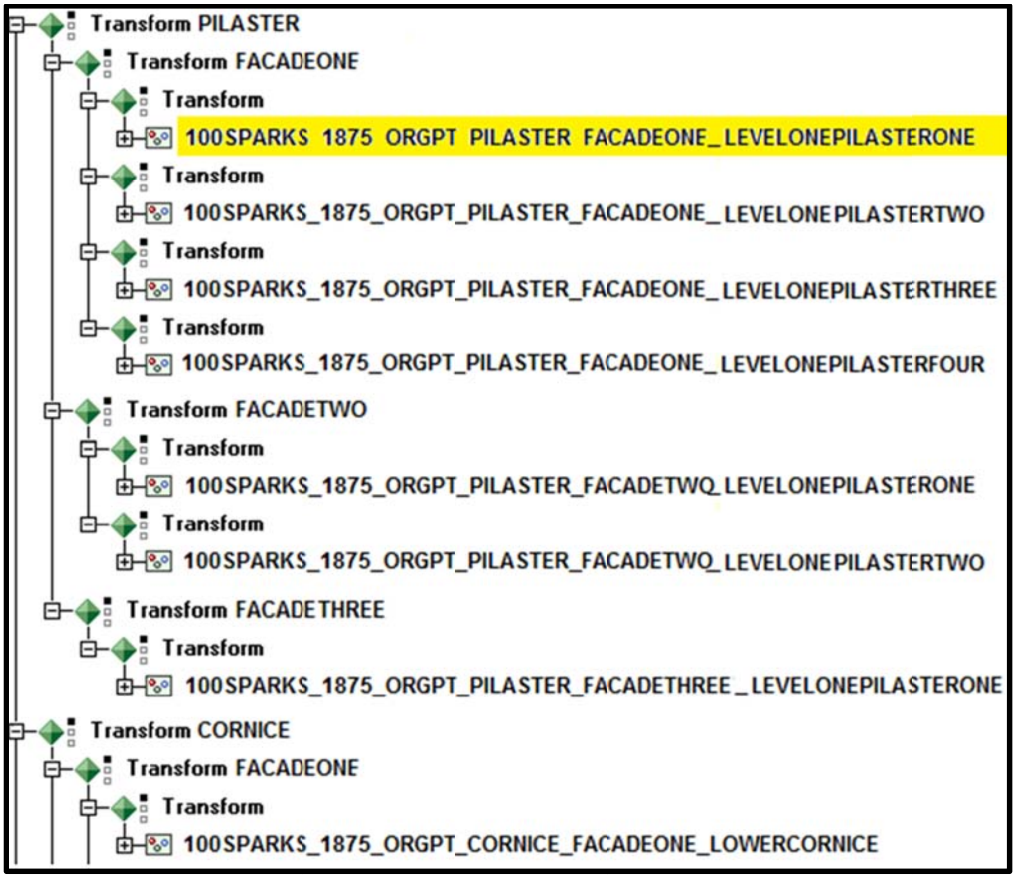
Figure Seven:

Figure Seven Continued:



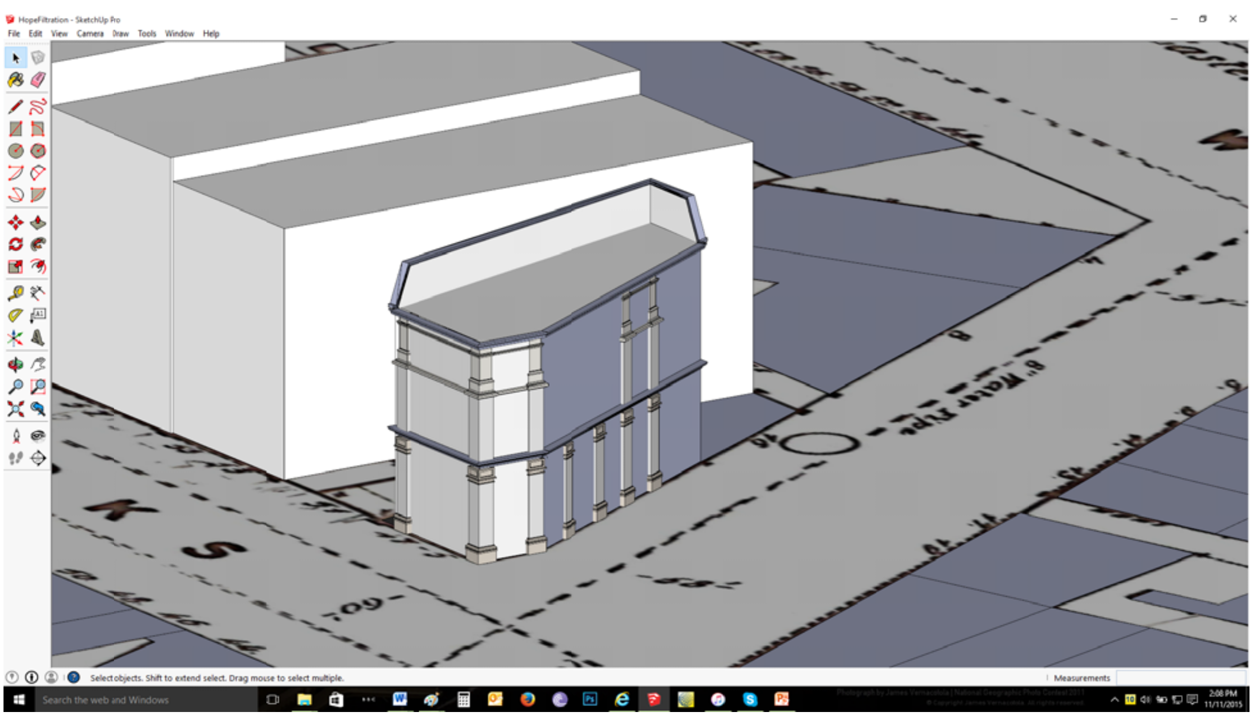
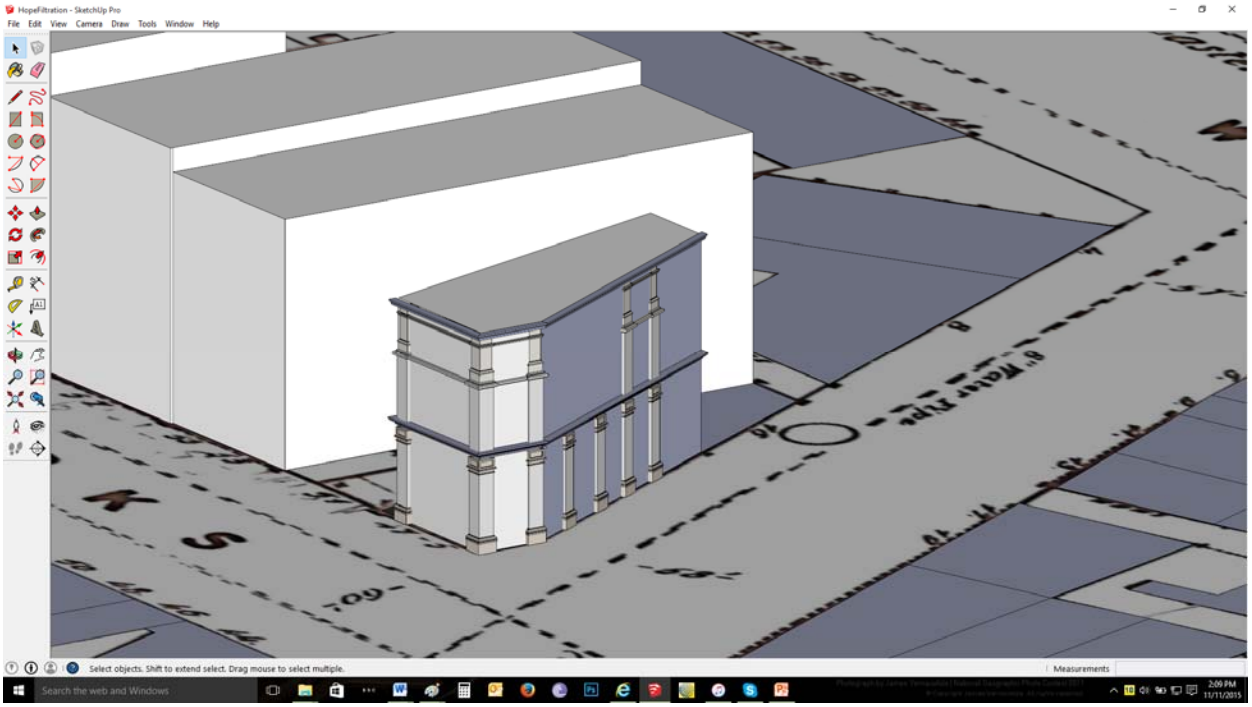
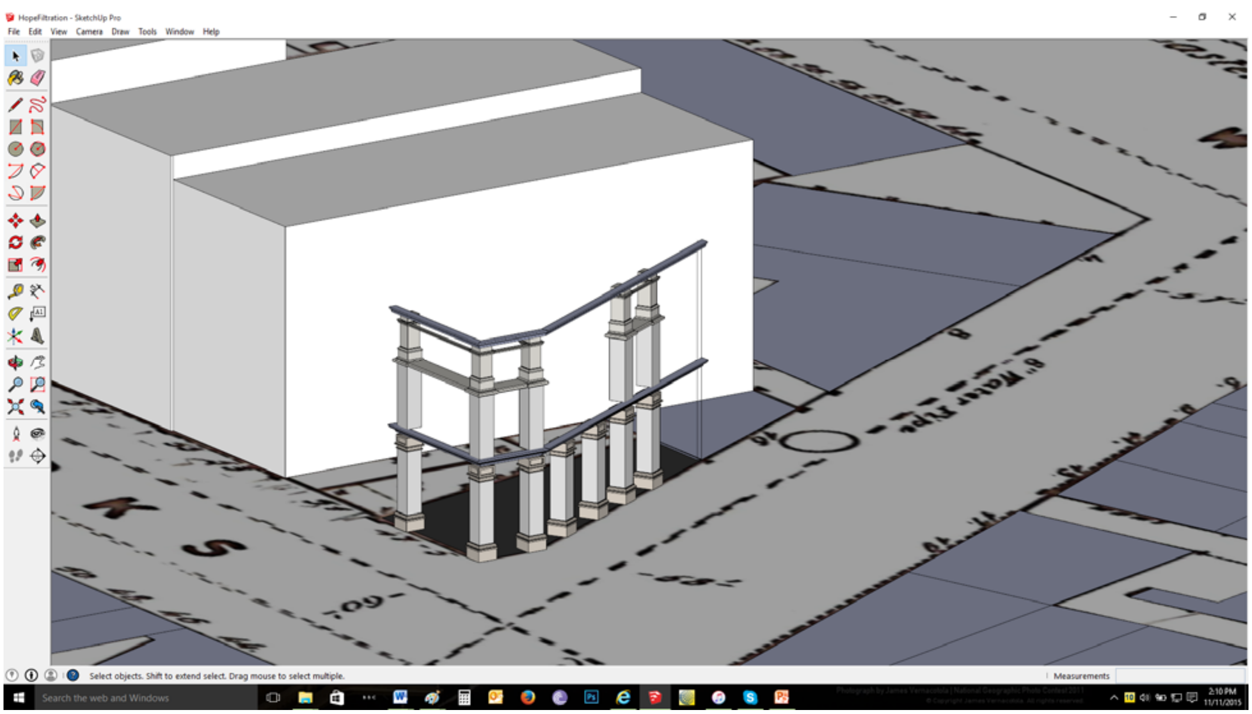


Figure Seven Continued:





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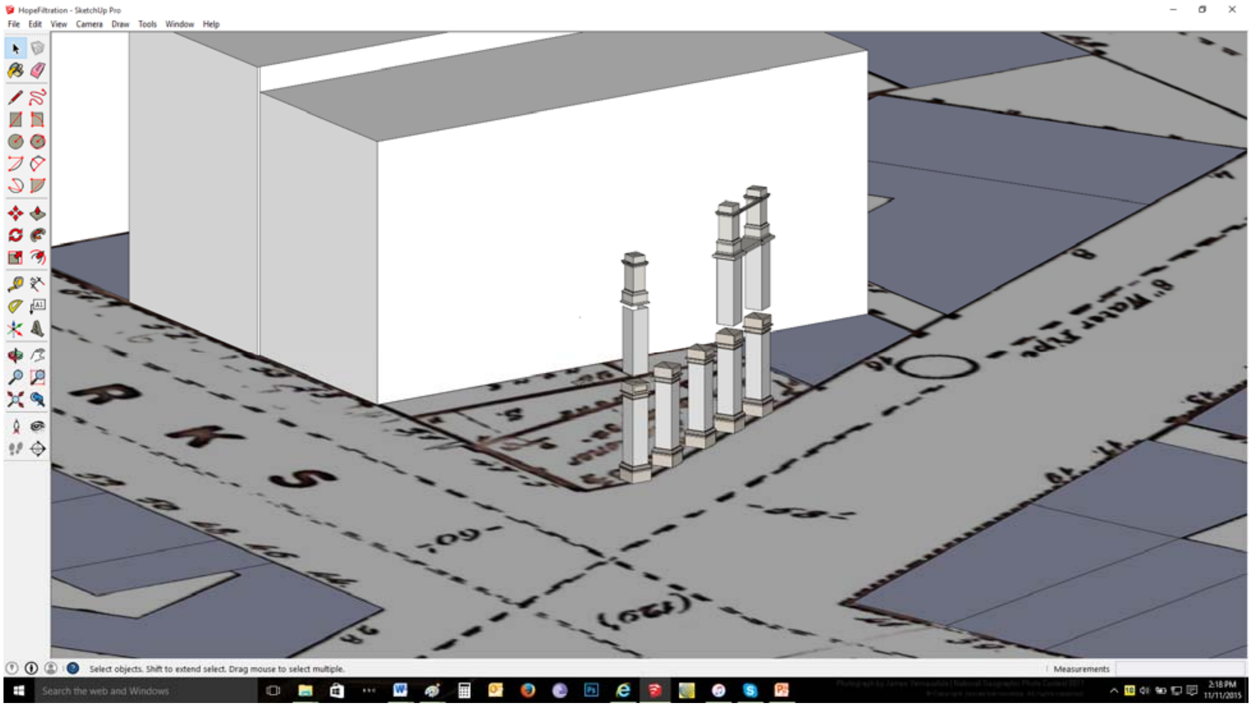

Figure Eight:

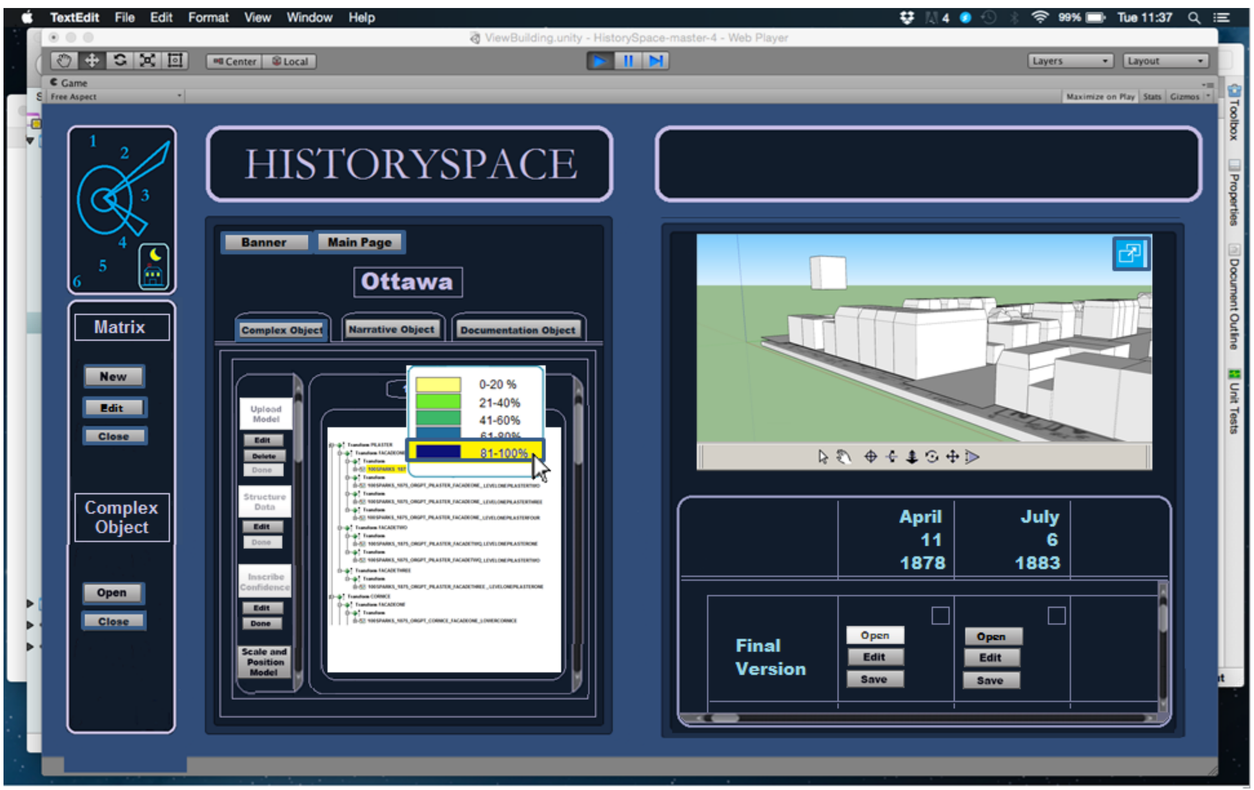

Figure Eight Continued:

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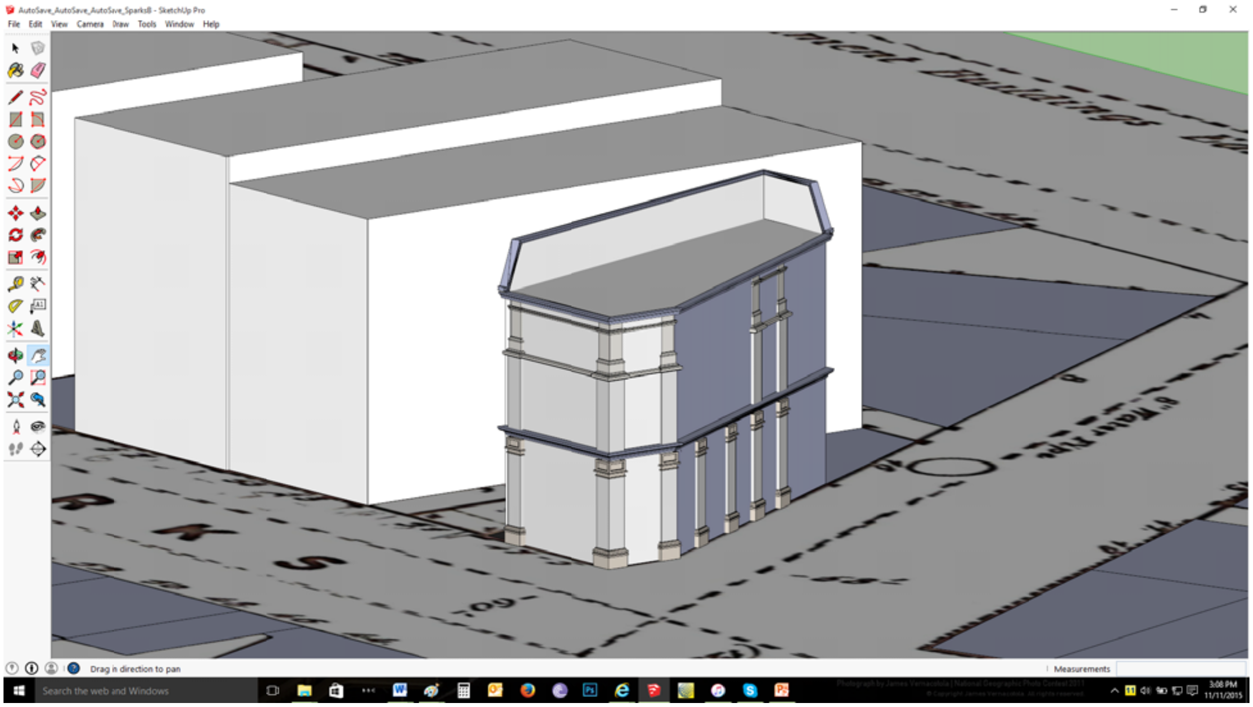


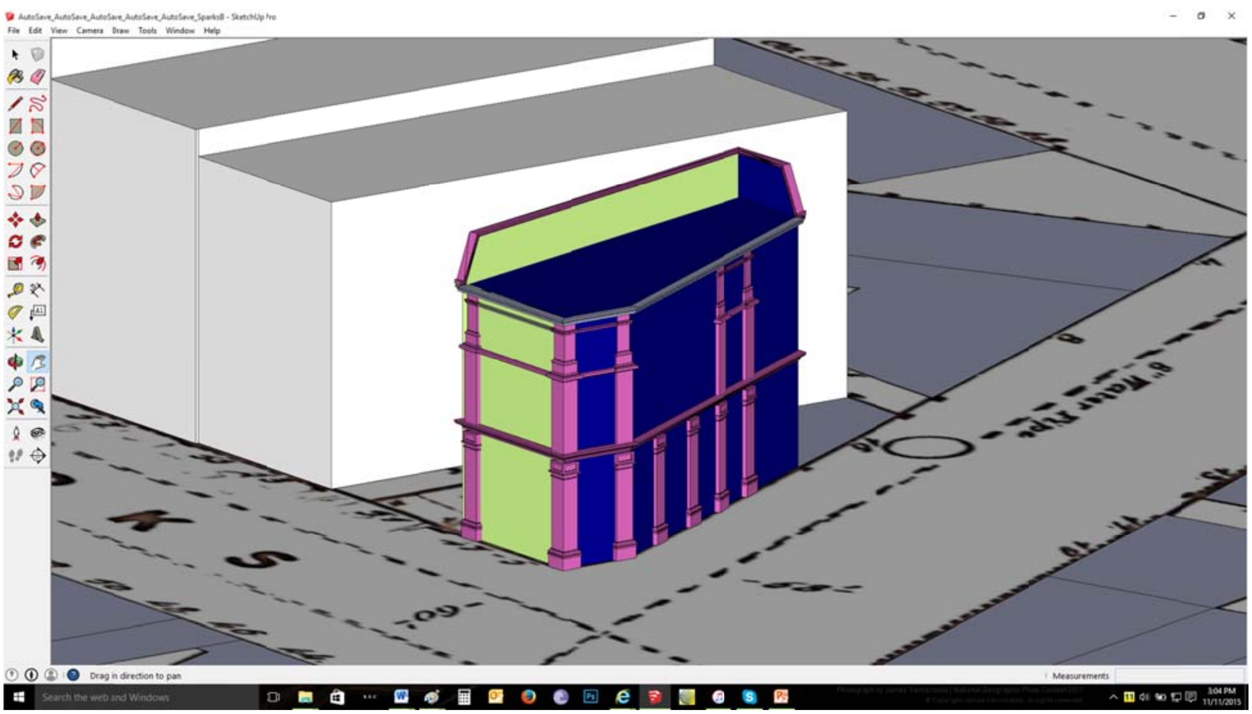
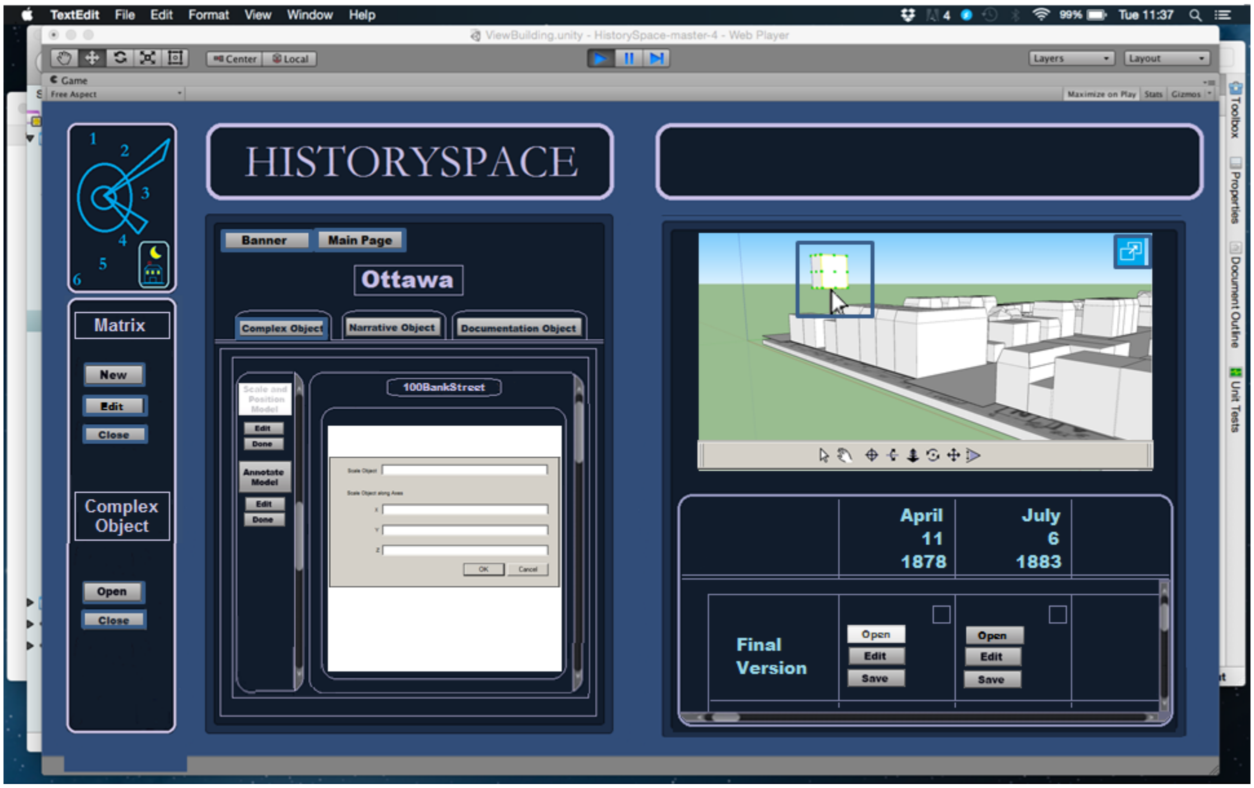


Figure Nine: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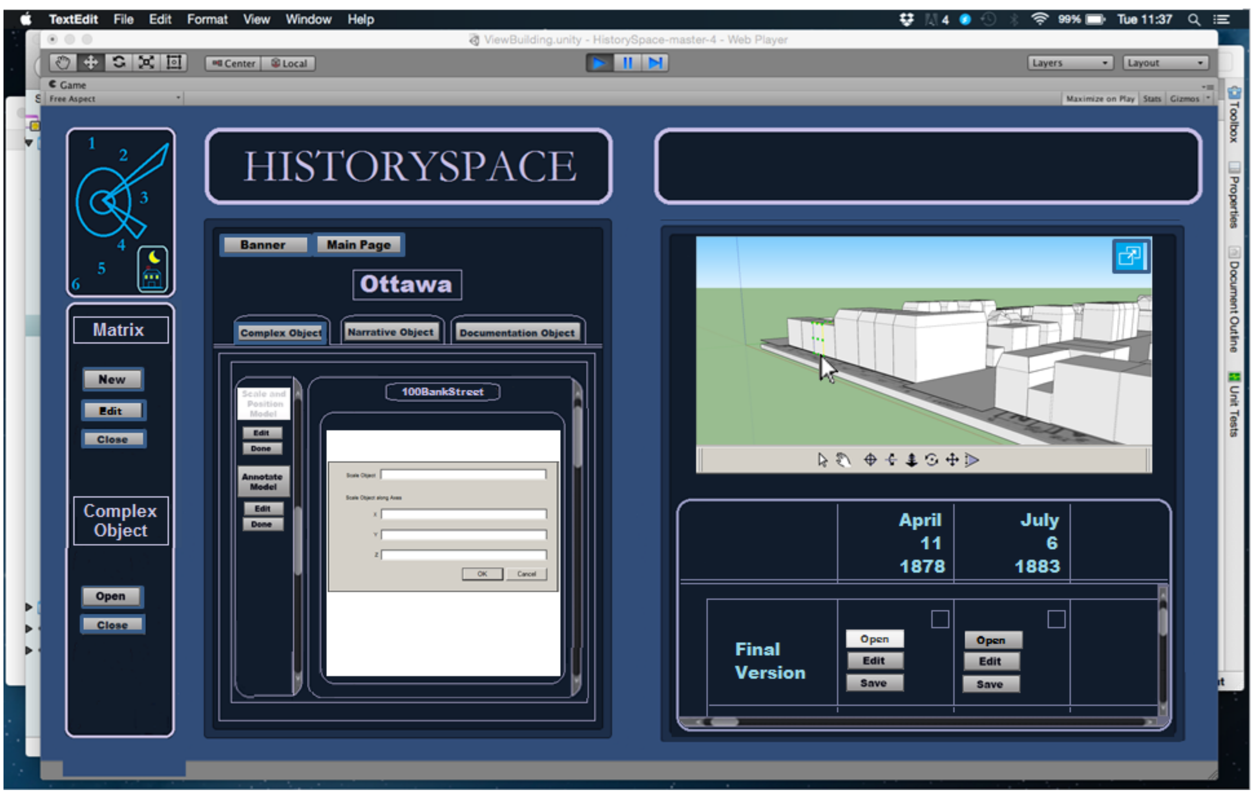
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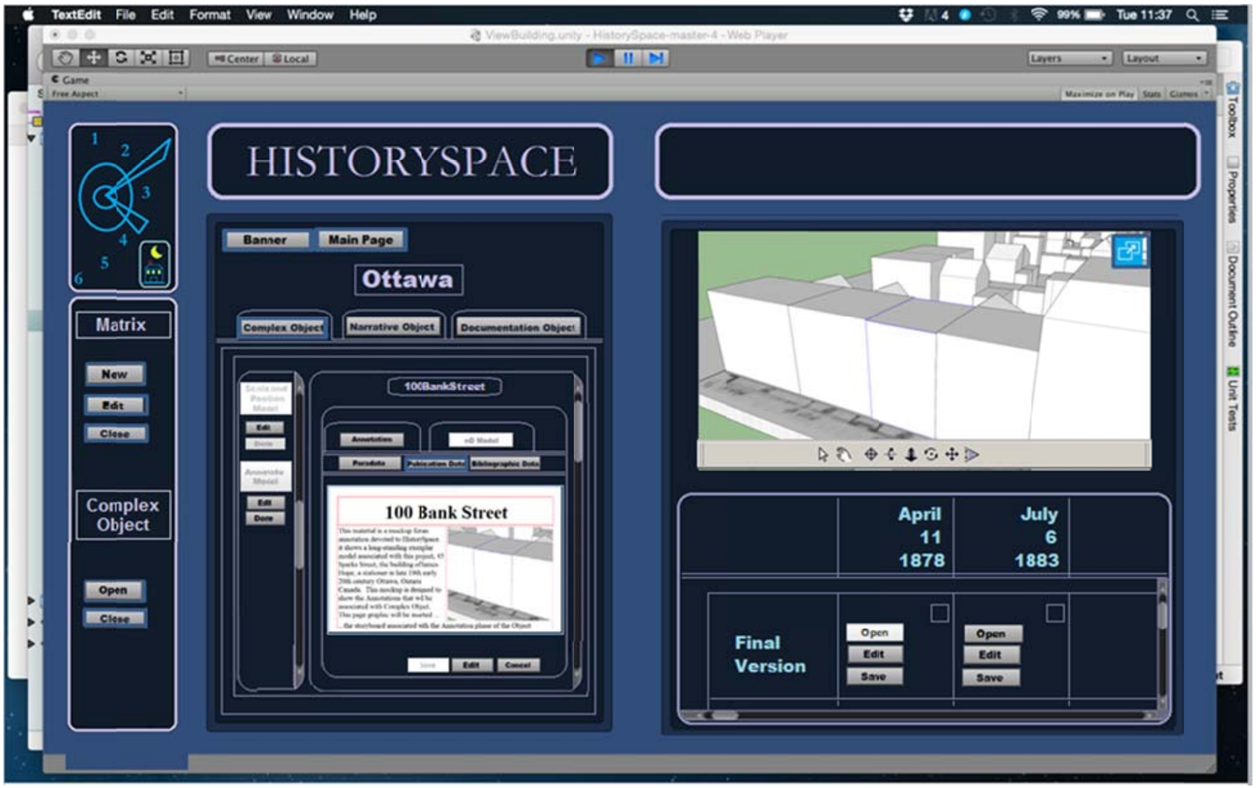
Figure Ten:



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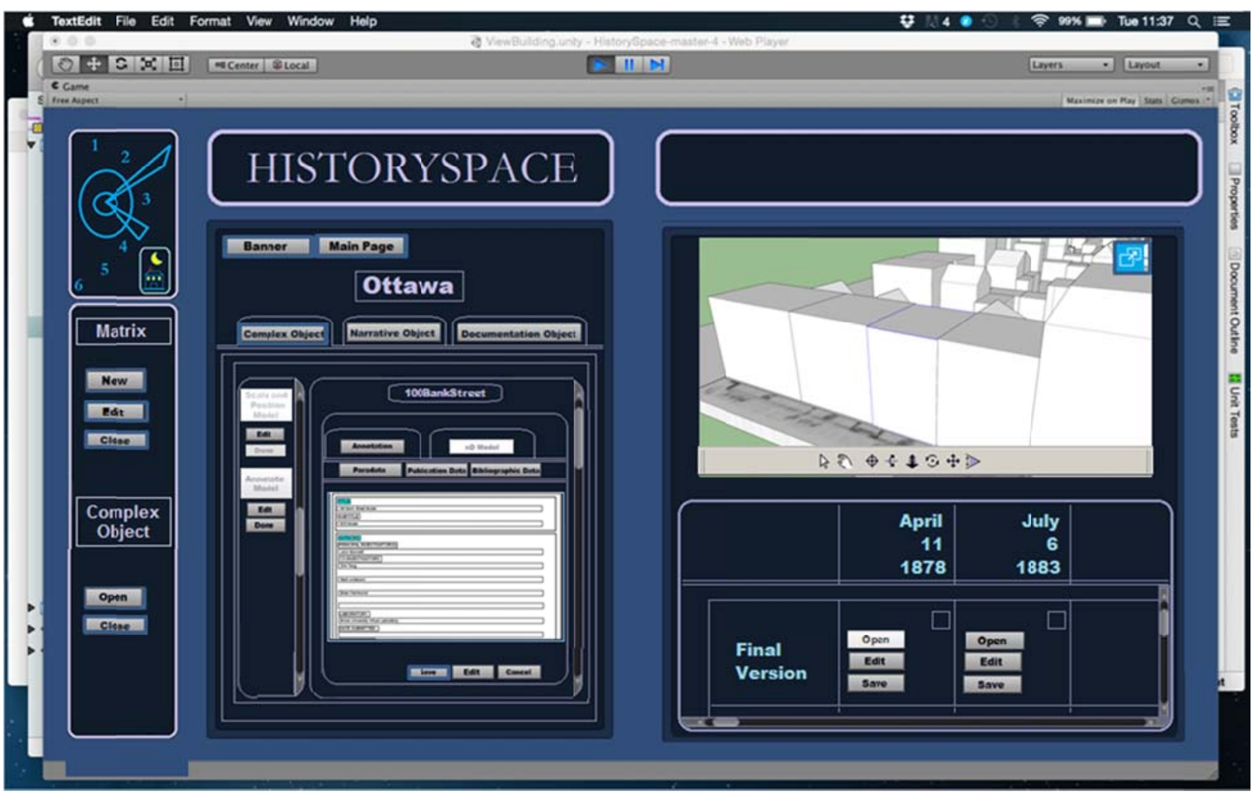

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In my section there are four things that I would like to briefly address: our method of software development; our rationale for using the *Unity 3D* game engine as the host for our software; our development of *StructureMorph*'s supporting infrastructure; and finally our progress in developing *StructureMorph* itself. To start, we are following an iterative design methodology, which is part of the reason we are presenting our ideas and work while we are still in the alpha stage of software development. Using this methodology allows us to engage with the community of researchers to design and build software that meets the needs of end users. We are seeking individuals from potential domains of use to test and evaluate our design once it is released in early January (Haughey, 2010) (Salisbury, 2003) (Kang, Park and Ki, 2003).

Our software, as John has just indicated, will be an application that will operate in conjunction with the *Unity 3D* game engine. There are several reasons why I, my colleague Brian Farrimond, and my student Eric Tang selected *Unity*, the first being that it is widely used, well supported and relatively easy to master. Open source alternates such as *Blender* provided the obvious attraction of being free, but we were loath to tie our software to an application that contained a difficult interface and provided a relatively poor level of instructional support. Further, *Blender's* advantage in terms of price – or lack thereof – has recently been undermined by the decision of game engine creators – such as *Unity and Unreal* – and 3D content creation vendors such as *Alias* to release free versions of their respective software packages. Finally, we selected *Unity* because of its capacity to import content directly from the web. There has been much discussion lately about the emergence of the Geo-Spatial Web, and we predict that eventuality will have three important consequents: many of its nodes will be constituted by digital globes such as Google Earth; three-dimensional and four-dimensional content will be extensible from one globe to another; and users will perceive that content using browsers with similar characteristics and interfaces to those now found in *Unity*. These modes of interaction include traditional methods that rely on a computer screen and mouse. They also include emerging non-traditional methods. Indeed, one of the powerful features that is supported by *Unity* is the ease with which gesture-based devices, such as the Microsoft Kinect camera or the Leap Motion sensor, can be utilized to explore and manipulate worlds. Given these assumptions, we opted to conduct our exploration of convergence and Complex Object construction within *Unity*.

To support that exploration, however, we also needed to pay due attention to *SturctureMorph*'s underlying infrastructure. Here, we are operating under the premise that scholarly virtual worlds will operate much like journals, with multiple contributors from multiple institutions making contributions toward the reconstruction of historic versions of locales such as Ottawa, Canada's capital. Such a scenario presumes that a project lead or editor will initiate a new project on a website and provide the content and data necessary to house submitted Complex Objects. It also presumes that the website will provide mechanisms that will automatically link submitted 4D models with the attribute data located on site. Put simply, we are assuming that historic digital sites will be generated collaboratively, and we have devoted the majority of our development time developing the software and website infrastructure that will permit that collaboration to occur.

We have, to start, designed our application so that it can be accessed either as an Internet application in a web browser, or as a desktop application (See Figure Eleven). *StructureMorph*'s capacity to utilize the processing power of either the user's client (their home computer) or the user's server (*StructureMorph*'s website) will enhance the application's accessibility, and enable users to collaborate with peers regardless of where they are located, or the computer at hand. We have also devoted substantial time to generating software that will automatically link submitted Complex Objects with the site's attribute data, and express that linkage by transforming the surface appearance of extant structures into symbolic mode, into a color reflecting the attributes and activities of building residents, as indicated in Figure Twelve).

A third focus for us was the design of a structure for deposited 3D models. Put simply, we designed an algorithm to split submitted content into smaller packets. There are several reasons why we took this step, the most fundamental being that it was a necessary transformation to permit the efficient dissemination and uploading of 3D content into a virtual world, and the efficient operation of the Complex Object and its accompanying matrix. Without that optimization, it would not be possible for users to manipulate a site's 3D data, or engage in efficient data queries (Millington, 2010) (Brinkman, 2008) (See Figure Thirteen).

Now that these essential elements are in place, we have begun the process of constructing the tools to support the workflow described by John. Our first step was to generate tools to enable project leads to establish specific cities as foci for researchers. They will be given tools and a workflow to upload a given city's underlying landscape, and polygons signifying city streets, city blocks and building footprints (Such as the landscape featured in Figure Fourteen). They will upload and situate the source Sandborn/Fire Insurance Maps representing the given city and time. In addition, we have completed construction of tools to support two steps in our Complex Object workflow, specifically the first and last. The tool shown in Figure Fifteen supports the uploading, scaling and placement of the displayed model into our virtual reconstruction of Ottawa. Our second tool will enable users to annotate metadata and narratives describing the history of the submitted structure. More specifically, it will enable users to inscribe the given model's publication and bibliographic data, and also to provide its paradata, the modeler's or modelers' account of the workflow and decision-making used to create the digital structure. We anticipate that the remaining tools supporting matrix definition, model structuring, and building constituent tagging will be completed by early January. Thank you for your kind attention.

Figure Eleven:

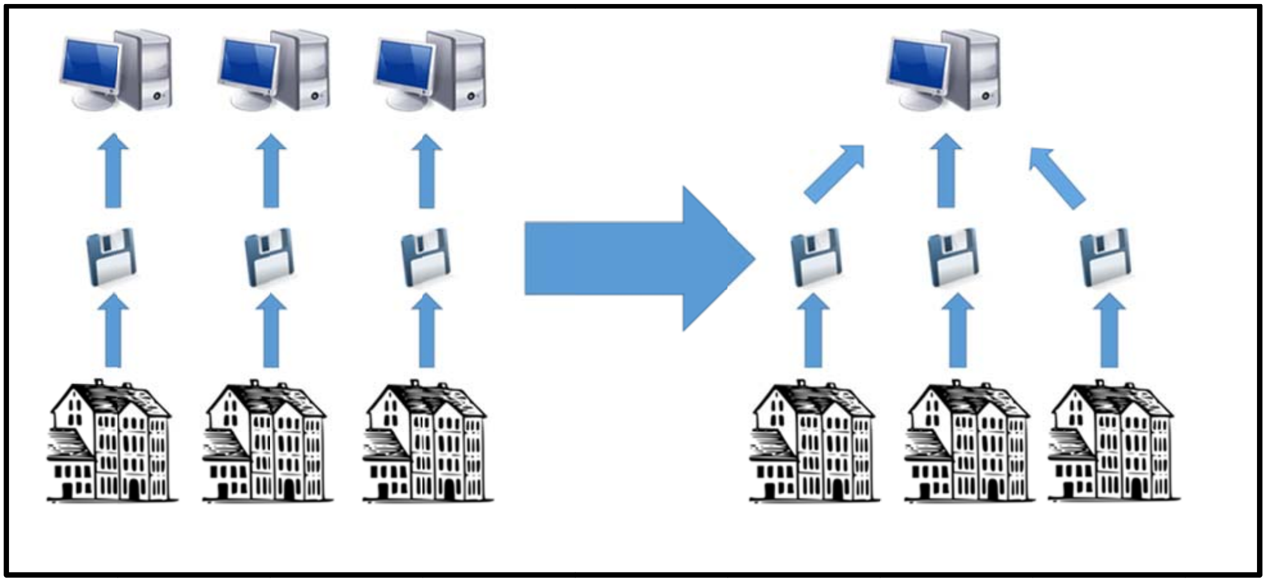
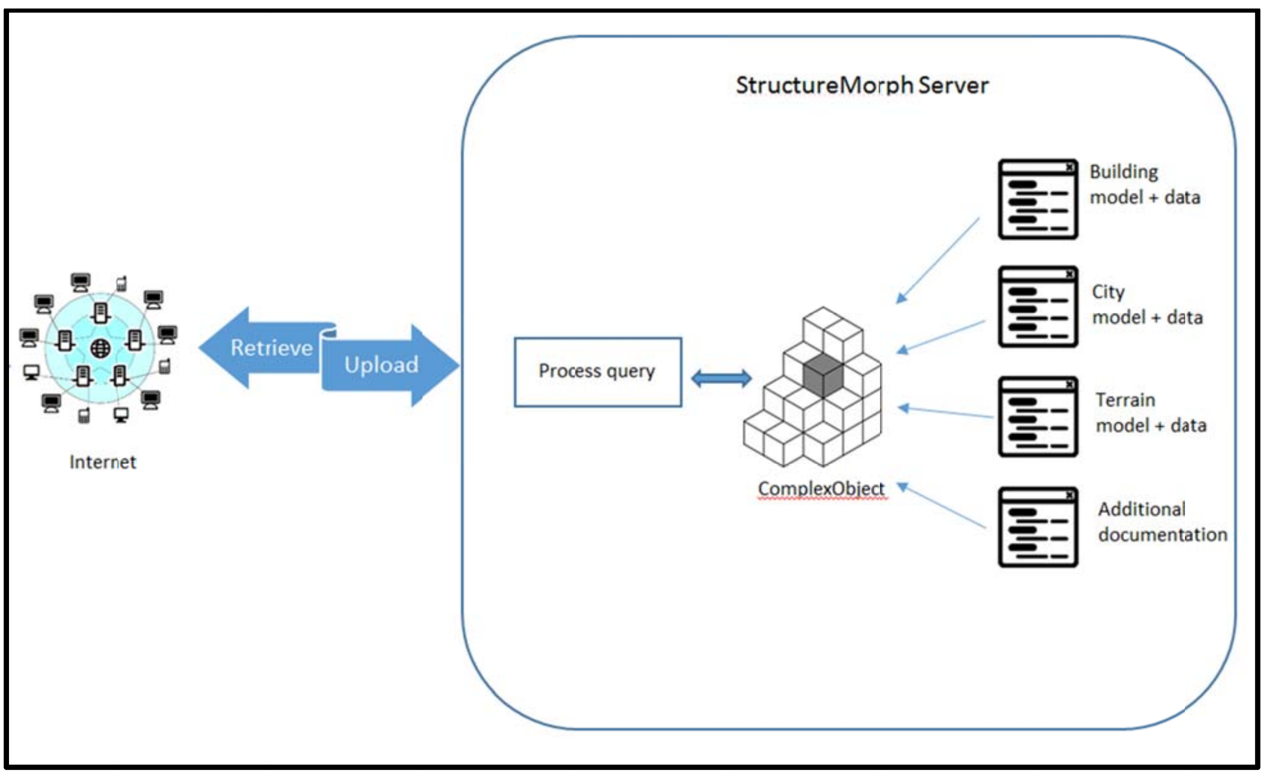


Figure Twelve:



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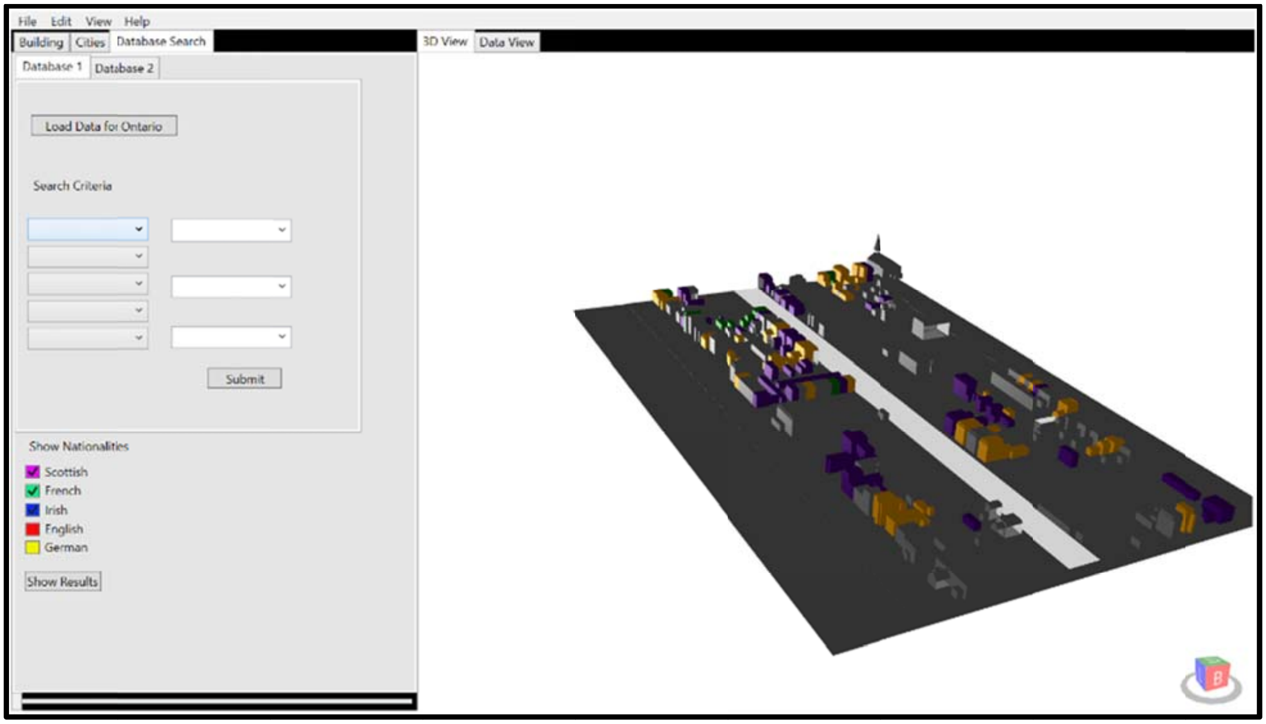


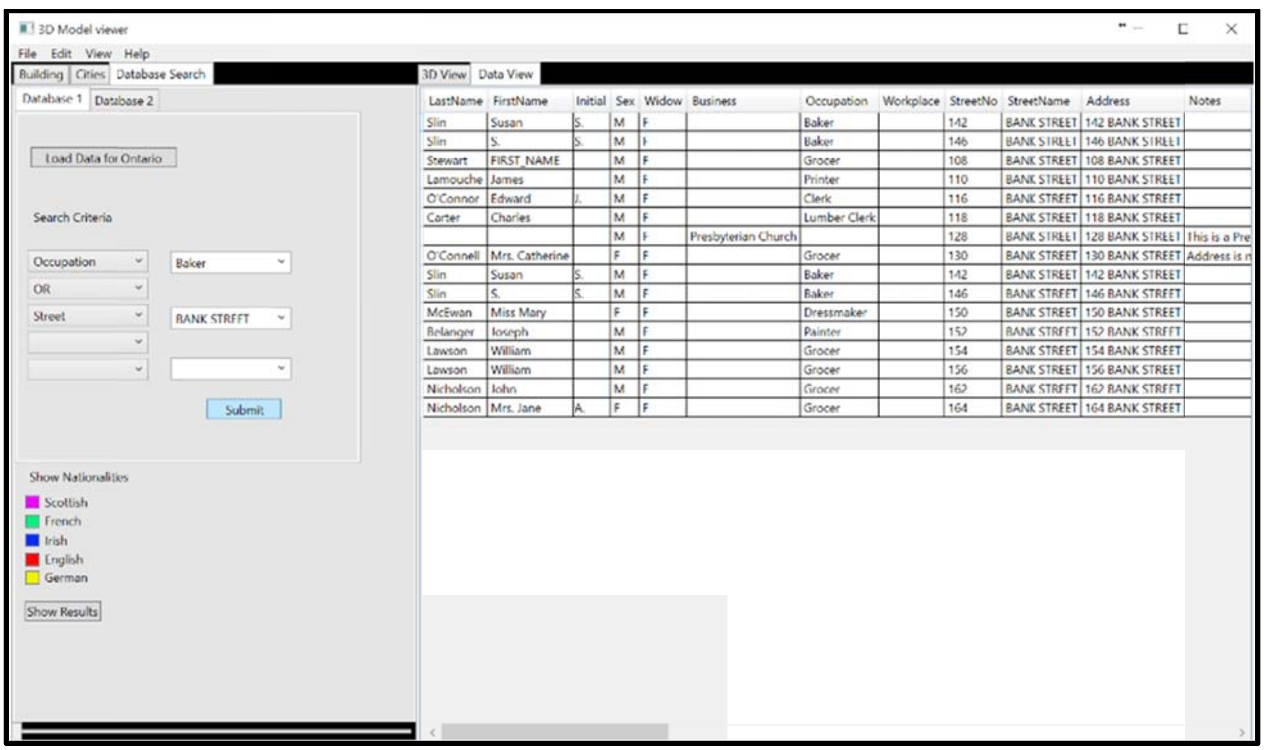


Figure Thirteen:

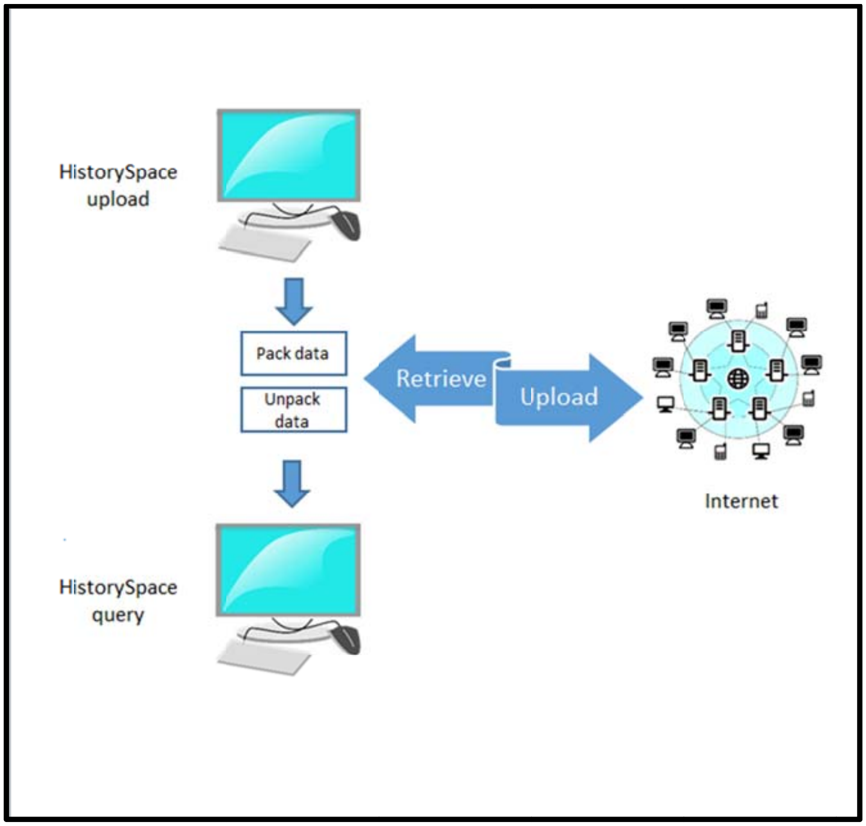


Figure Fourteen:

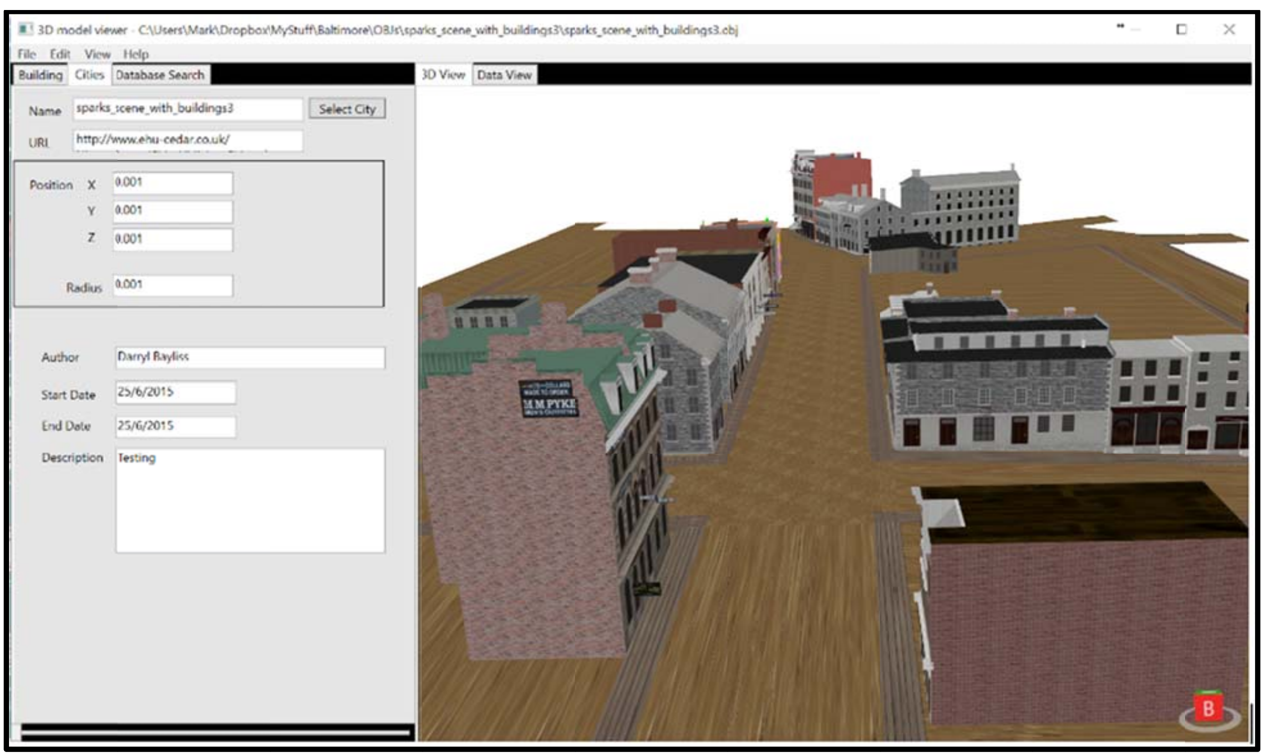
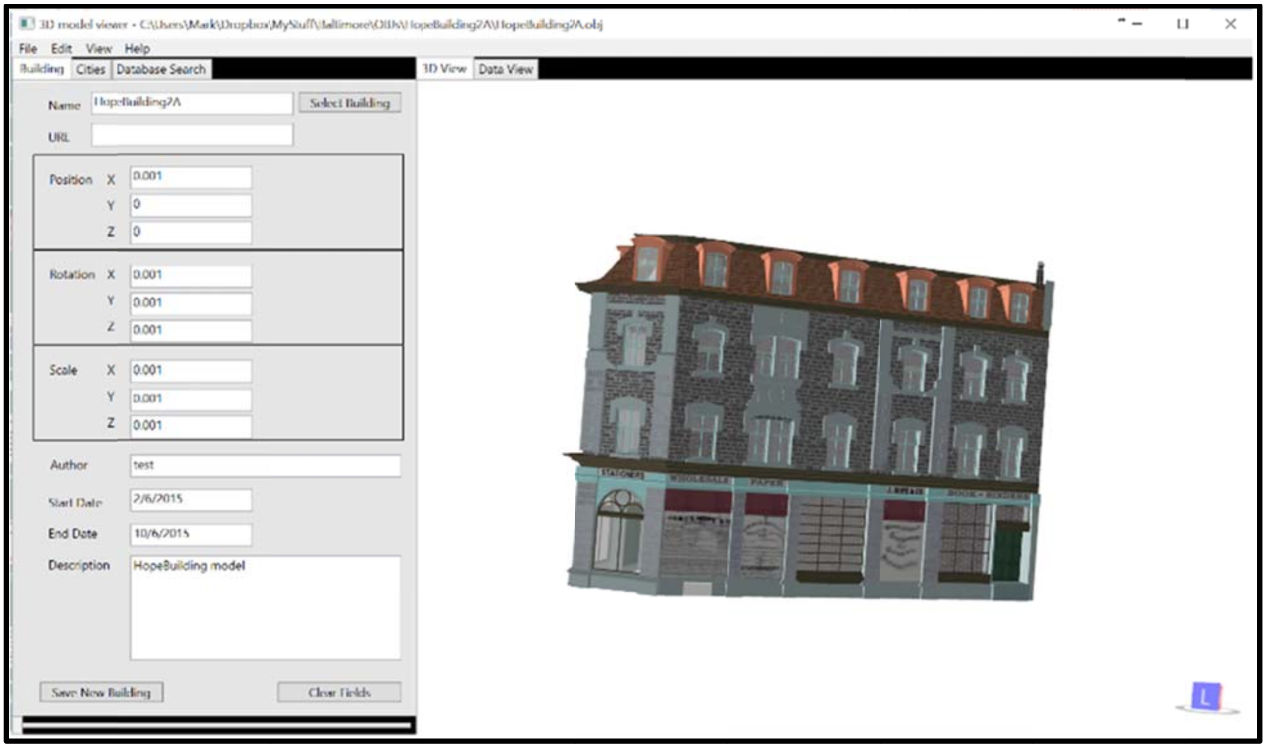


Figure Fifteen:



References:

Armstrong, Marc. (1995) "Is there a Role for High Performance Computing in GIS?" In *Journal of the Urban and Regional Information Systems Association* 7(1): 7-10.

Bennett, David A., and Tang, Wenwu. (2008) "Mobile, Aware, Intelligent Agents (MAIA)." in *Understanding Dynamics of Geographic Domains* Eds. Kathleen Stewart Hornsby and May Yuan (Boca Raton, Florida: CRC Press): 171–86

Bodenhamer, David. (2010) "The Potential of Spatial Humanities," in *The Spatial Humanities: GIS and the Future of Humanities Scholarship,* David Bodenhamer, John Corrigan, and Trevor M. Harris, Eds. (Bloomington, Indiana: Indiana University Press): 14-30.

Bonnett, John. (2009) "High-Performance Computing: An Agenda for the Social Sciences and the Humanities in Canada." In *Digital Studies*. 1(2).

Bonnett, John. (2015) "A Plea for Design: Historians, Digital Platforms, and the Mindful Dissemination of Content and Concepts," in *Journal of the Canadian Historical Association*. 25(2): 189-231.

Brinkman, Ron. (2008) *The Art and Science of Digital Compositing: Second Edition -- Techniques for Visual Effects, Animation and Motion Graphics* (The Morgan Kaufmann Series in Computer Graphics). London: Morgan Kaufmann.

Brynjolfsson, Erik and McAfee, Andrew. (2014) *The Second Machine Age: Work, Progress, and Prosperity in a Time of Brilliant Technologies* New York, NY: W.W. Norton Press.

Delve, Janet et al. Eds. (2012) *The Preservation of Complex Objects: Volume 1, Visualisations and Simulations* Portsmouth, UK: Portsmouth University.

Guldi, Jo and Armitage, David. (2014) *The History Manifesto* Cambridge, UK: Cambridge University Press.

Harris, Trevor M., Corrigan, John, and Bodenhamer, David J. (2010) "Challenges for the Spatial Humanities," in *The Spatial Humanities: GIS and the Future of Humanities Scholarship,* David Bodenhamer, John Corrigan, and Trevor M. Harris, Eds. (Bloomington, Indiana: Indiana University Press): 167-176.

Harris, Trevor M., Rouse, L. Jesse, and Bergeron, Susan. (2010) "The Geospatial Semantic Web, Pareto GIS, and the Humanities," in *The Spatial Humanities: GIS and the Future of Humanities Scholarship,* David Bodenhamer, John Corrigan, and Trevor M. Harris, Eds. (Bloomington, Indiana: Indiana University Press): 124-142.

Haughey, D. (2010). "Waterfall v Agile: How Should I Approach My Software Development Project? (Unilever)" at *Project Smart* Available on-line:

http://www.projectsmart.co.uk/waterfall-v-agile-how-should-i-approach-my-software-development-project.html [July 31, 2014]

Jockers, Matthew L. (2013) *Macroanalysis: Digital Methods and Literary History* Urbana, IL: University of Illinois Press.

Kang, I., Park, Y., and Ki, Y. (2003) "A framework for designing a workflow based knowledge map", in *Business Process Management Journal* 9(3): 281-294,

Kurzweil, Ray. (1999) *The Age of Spiritual Machines* New York, NY: Penguin Press.

Lock, Gary. (2010) "Representations of Space and Place in the Humanities" in *The Spatial Humanities: GIS and the Future of Humanities Scholarship,* David Bodenhamer, John Corrigan, and Trevor M. Harris, Eds. (Bloomington, Indiana: Indiana University Press): 89-109.

Manning, Patrick. (2013) *Big Data in History* New York: Palgrave Macmillan.

Millington, Ian. (2010) *Game Physics Engine Development*, Morgan Kaufmann.

Peddie, Jon. (2001) "Digital Media Technology: Industry Trends and Developments," in *IEEE Computer Graphics and Applications*, 21(1): 27-31.

Stojanovic, Natalija and Stojanovic, Dragan. (2013) "High-Performance Processing of Geospatial Data on Networks of Workstations." In *International Journal of Reasoning-based Intelligent Systems* 5(1): 42-49.

Yuan, May. (2010) "Mapping Text," in *The Spatial Humanities: GIS and the Future of Humanities Scholarship,* David Bodenhamer, John Corrigan, and Trevor M. Harris, Eds. (Bloomington, Indiana: Indiana University Press): 109-123.

Yuan, May and Hornsby, Kathleen. (2008) *Computation and Visualization for Understanding Dynamics in Geographic Domains* Boca Raton, Florida: CRC Press.